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Tone

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(54) **INK JET PRINTING APPARATUS, PRINT HEAD RECOVERY DEVICE AND PRINT HEAD RECOVERY METHOD**

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B41J 2/165 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 2/16532*** (2013.01); *B41J 2002/16573* (2013.01)

(58) **Field of Classification Search**
USPC 347/34, 29–30
See application file for complete search history.

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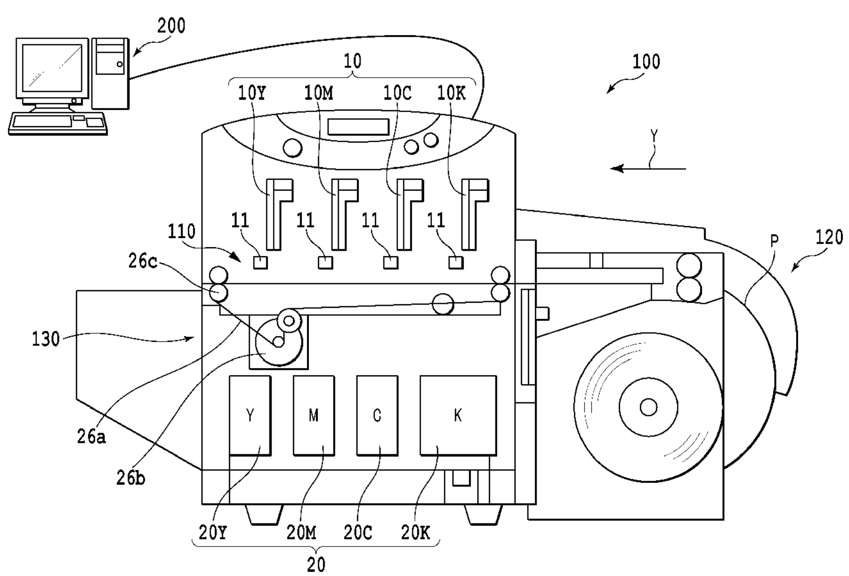
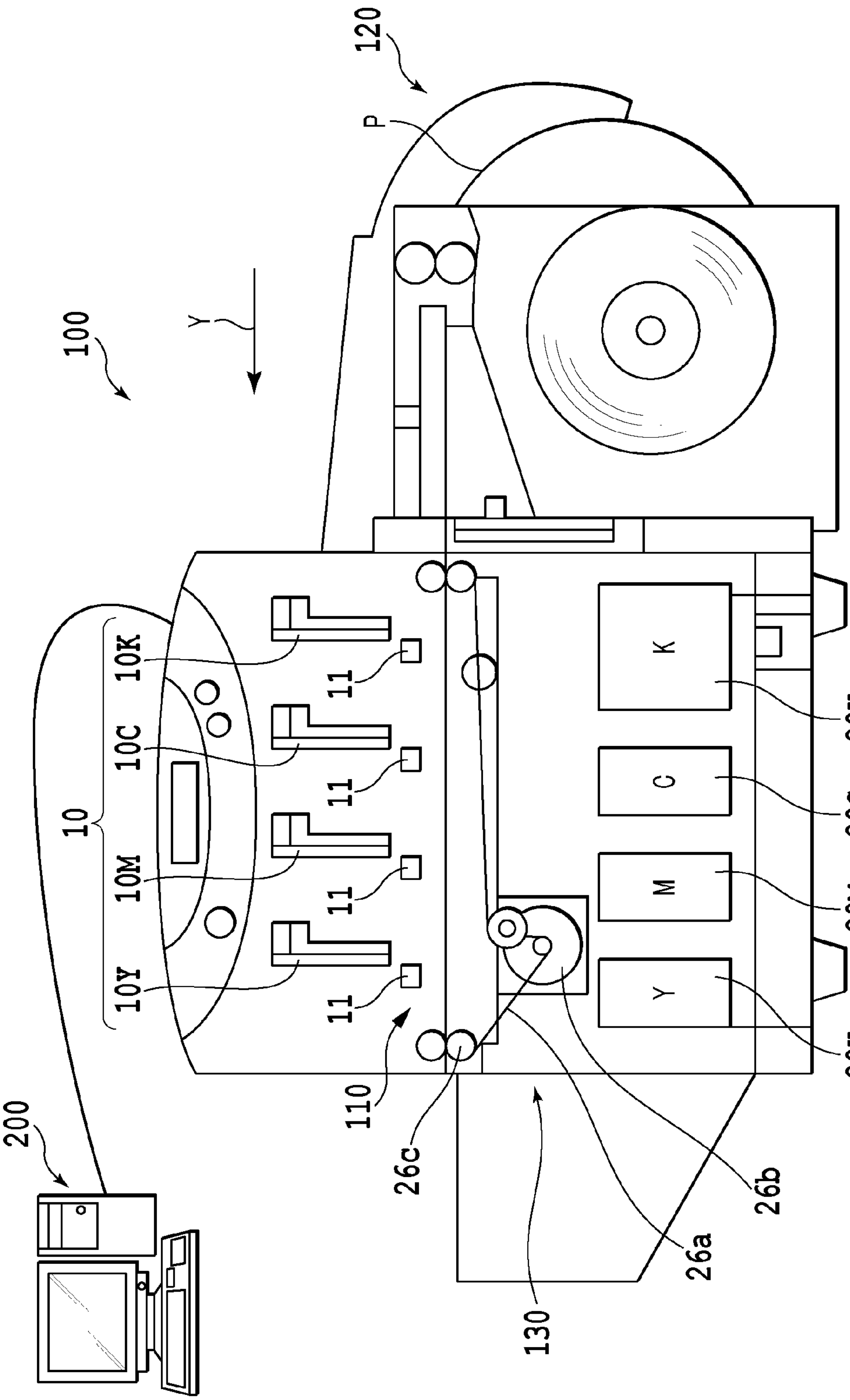
Primary Examiner — Jason Uhlenhake
(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

In an ink jet printing apparatus prints an image by employing a print head capable of ejecting ink from ejection ports, a suction unit draws ink from the ejection ports into an interior of the cap by applying a suction force to the interior of a cap that is covering the ejection ports. An atmosphere communication unit exposes to the atmosphere the interior of the cap that is covering the ejection ports, and a pressure increase unit increases a pressure in an internal of the print head. A control unit permits the suction unit to apply the suction force to the interior of the cap, and permits the pressure increase unit to increase the pressure in the internal of the print head before the atmosphere communication unit exposes the interior of the cap to the atmosphere in a state where the ejection ports is covered with the cap.

8 Claims, 14 Drawing Sheets

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130
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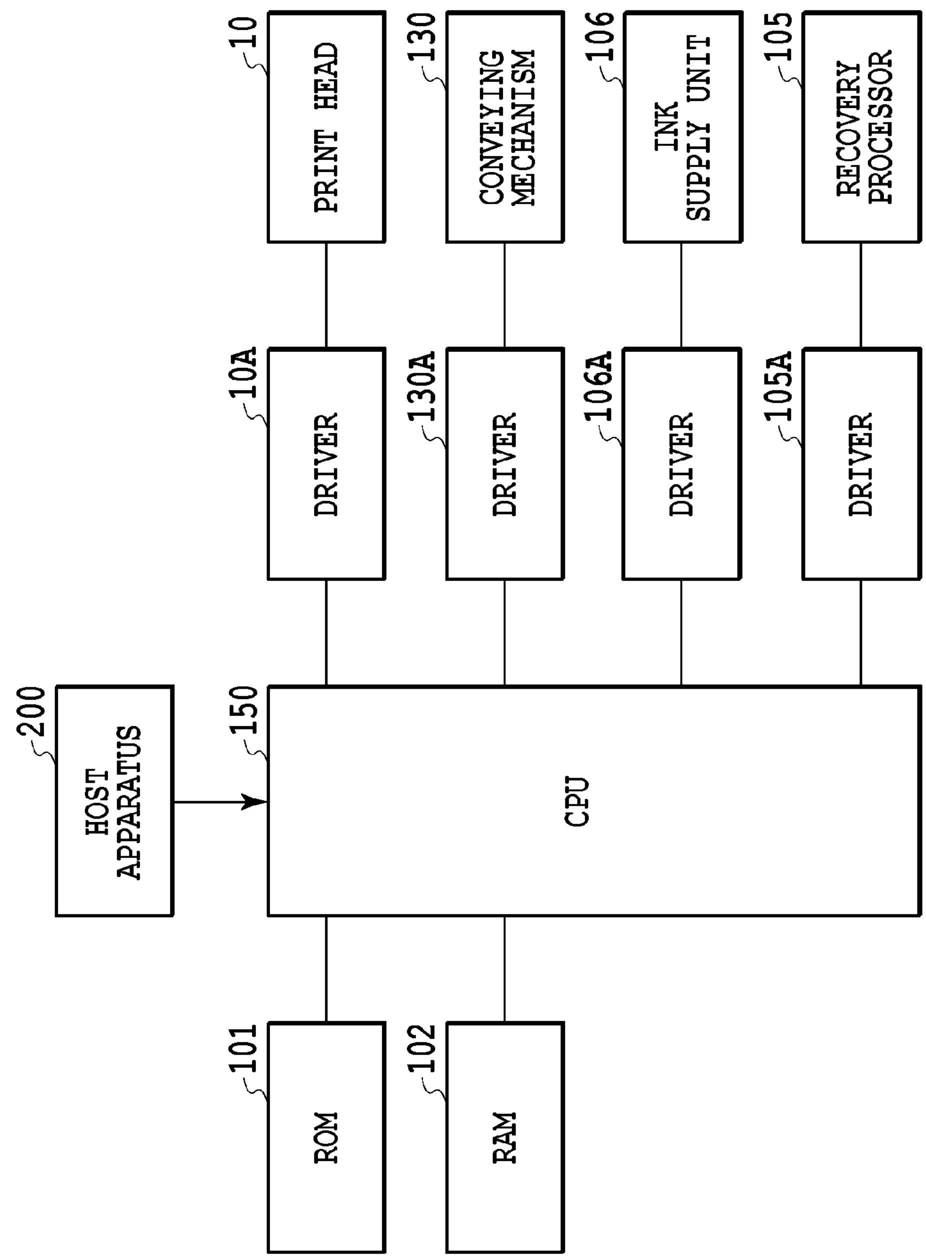
26a
26b
26c

FIG.1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PRINT HEAD
130
CONVEYING MECHANISM
106
INK SUPPLY UNIT
105
RECOVERY PROCESSOR
10A
DRIVER
130A
DRIVER
106A
DRIVER
105A
DRIVER
200
HOST APPARATUS
150
CPU
101
ROM
102
RAM

FIG.2

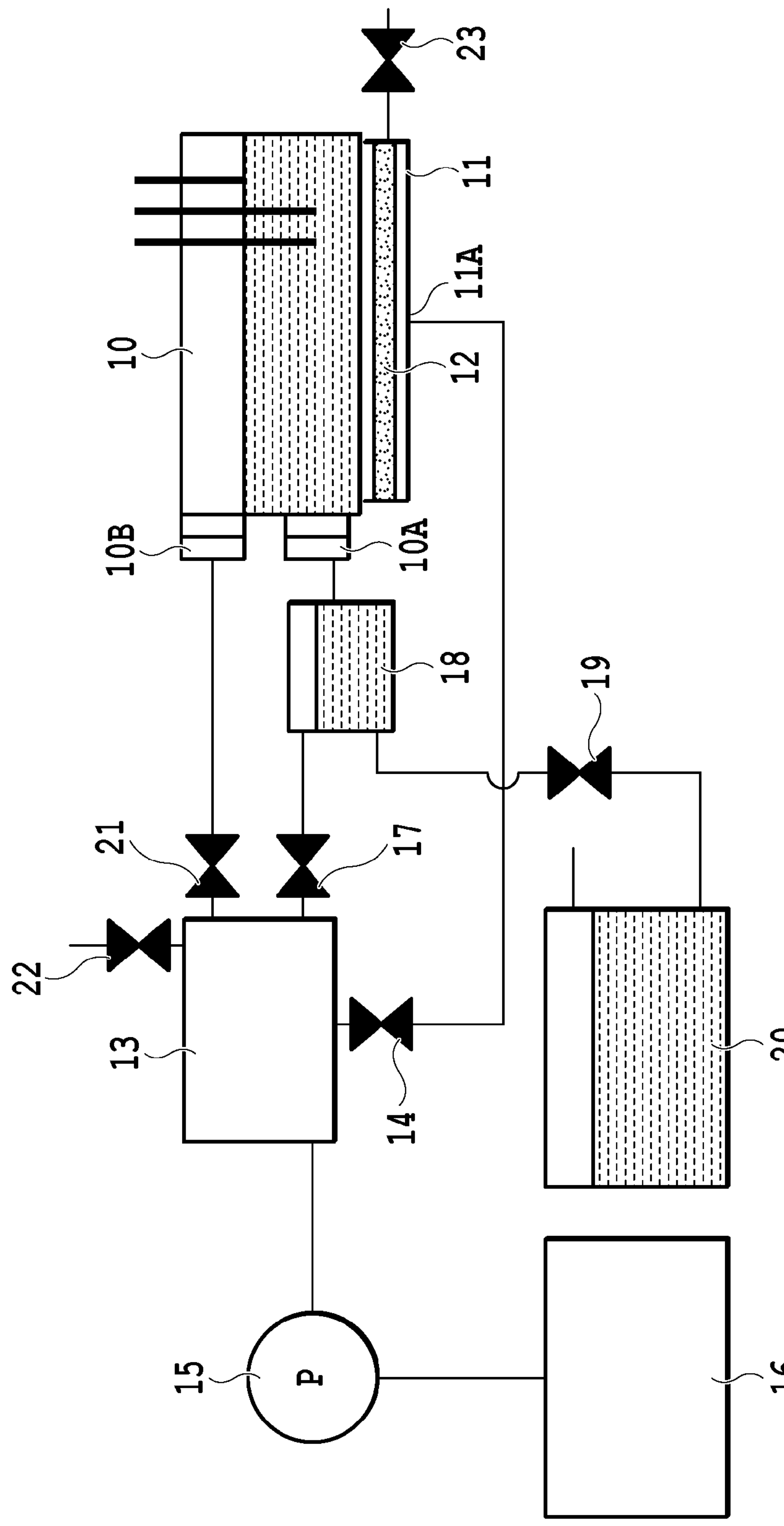


FIG.3

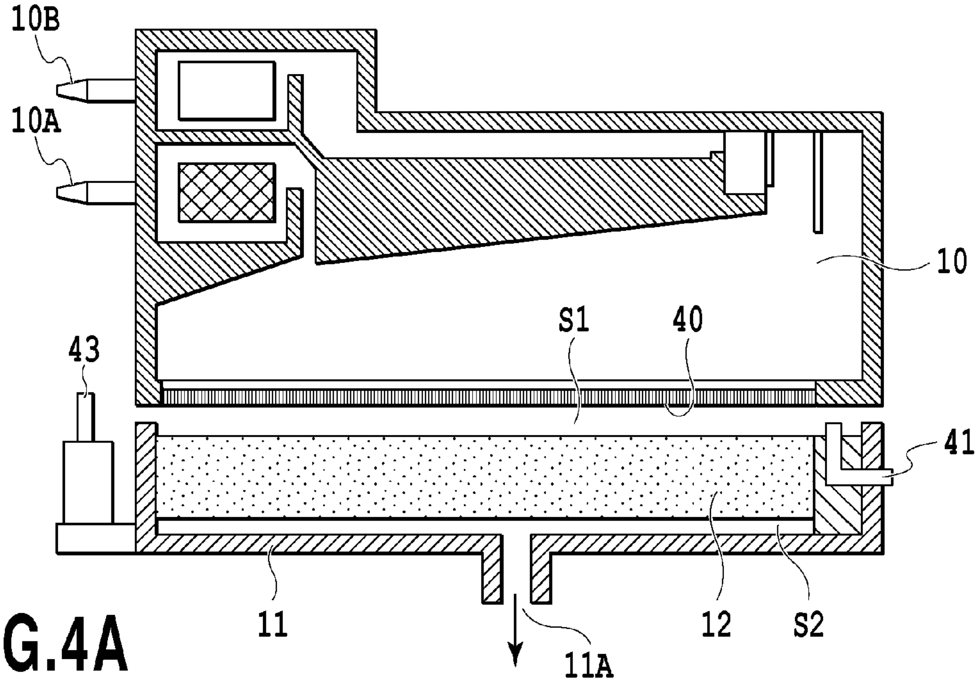


FIG.4A

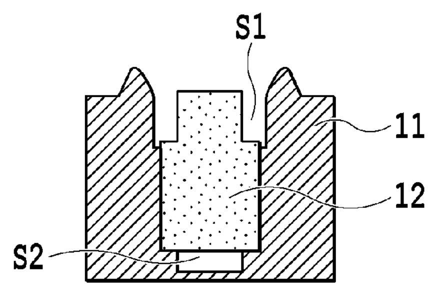


FIG.4B

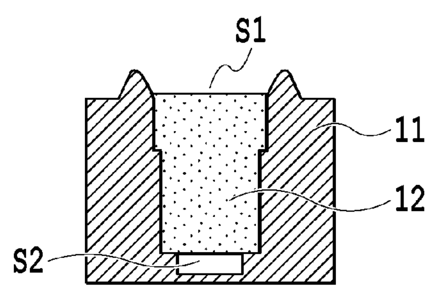


FIG.4C

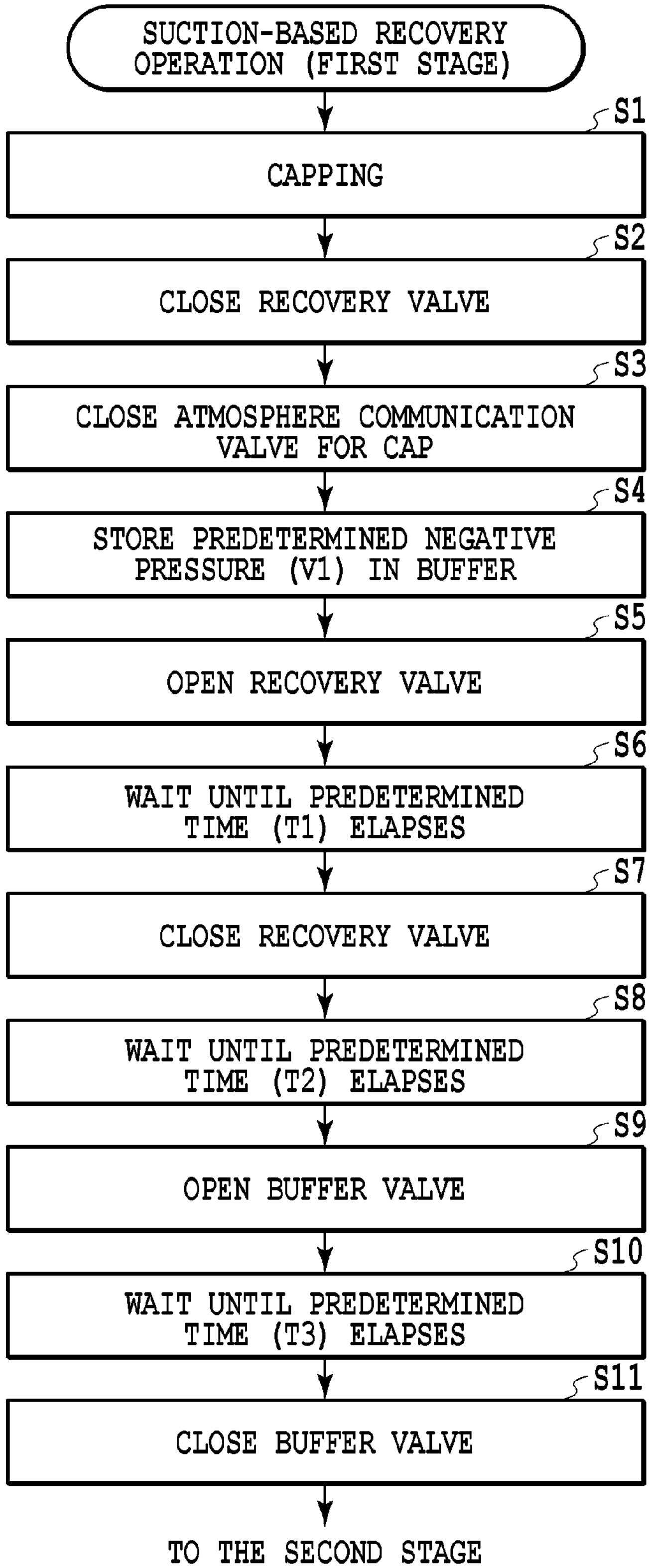

SUCTION-BASED RECOVERY OPERATION (FIRST STAGE)
S1
CAPPING
S2
CLOSE RECOVERY VALVE
S3
CLOSE ATMOSPHERE COMMUNICATION VALVE FOR CAP
S4
STORE PREDETERMINED NEGATIVE PRESSURE (V1) IN BUFFER
S5
OPEN RECOVERY VALVE
S6
WAIT UNTIL PREDETERMINED TIME (T1) ELAPSES
S7
CLOSE RECOVERY VALVE
S8
WAIT UNTIL PREDETERMINED TIME (T2) ELAPSES
S9
OPEN BUFFER VALVE
S10
WAIT UNTIL PREDETERMINED TIME (T3) ELAPSES
S11
CLOSE BUFFER VALVE
TO THE SECOND STAGE

FIG.5

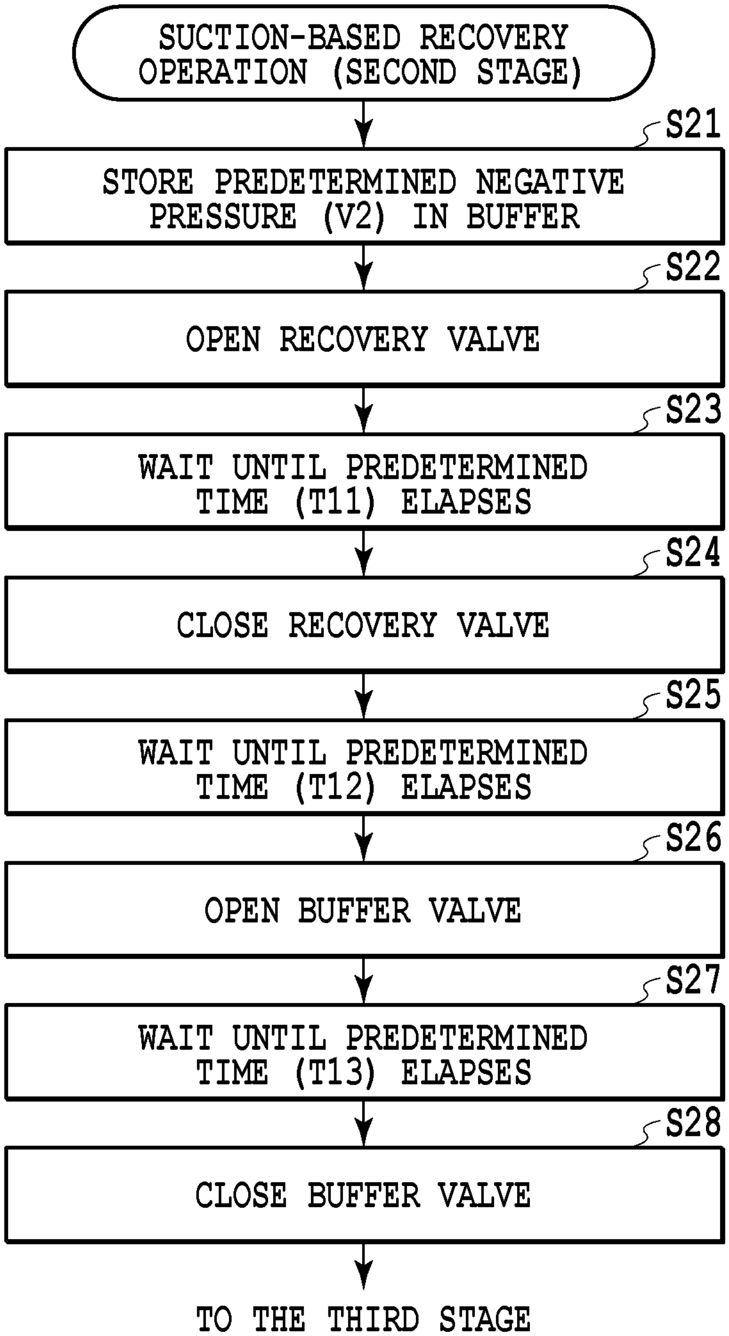

SUCTION-BASED RECOVERY OPERATION (SECOND STAGE)
S21
STORE PREDETERMINED NEGATIVE PRESSURE (V2) IN BUFFER
S22
OPEN RECOVERY VALVE
S23
WAIT UNTIL PREDETERMINED TIME (T11) ELAPSES
S24
CLOSE RECOVERY VALVE
S25
WAIT UNTIL PREDETERMINED TIME (T12) ELAPSES
S26
OPEN BUFFER VALVE
S27
WAIT UNTIL PREDETERMINED TIME (T13) ELAPSES
S28
CLOSE BUFFER VALVE
TO THE THIRD STAGE

FIG.6

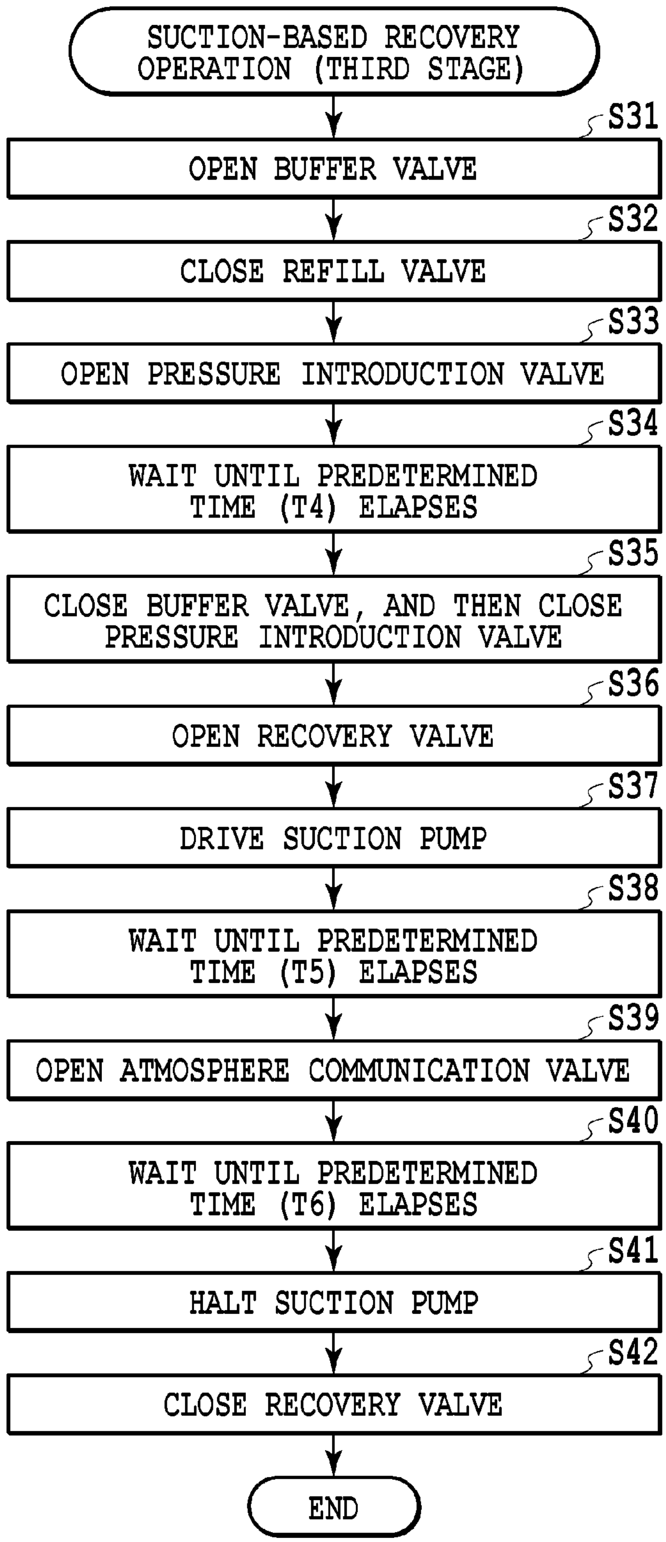
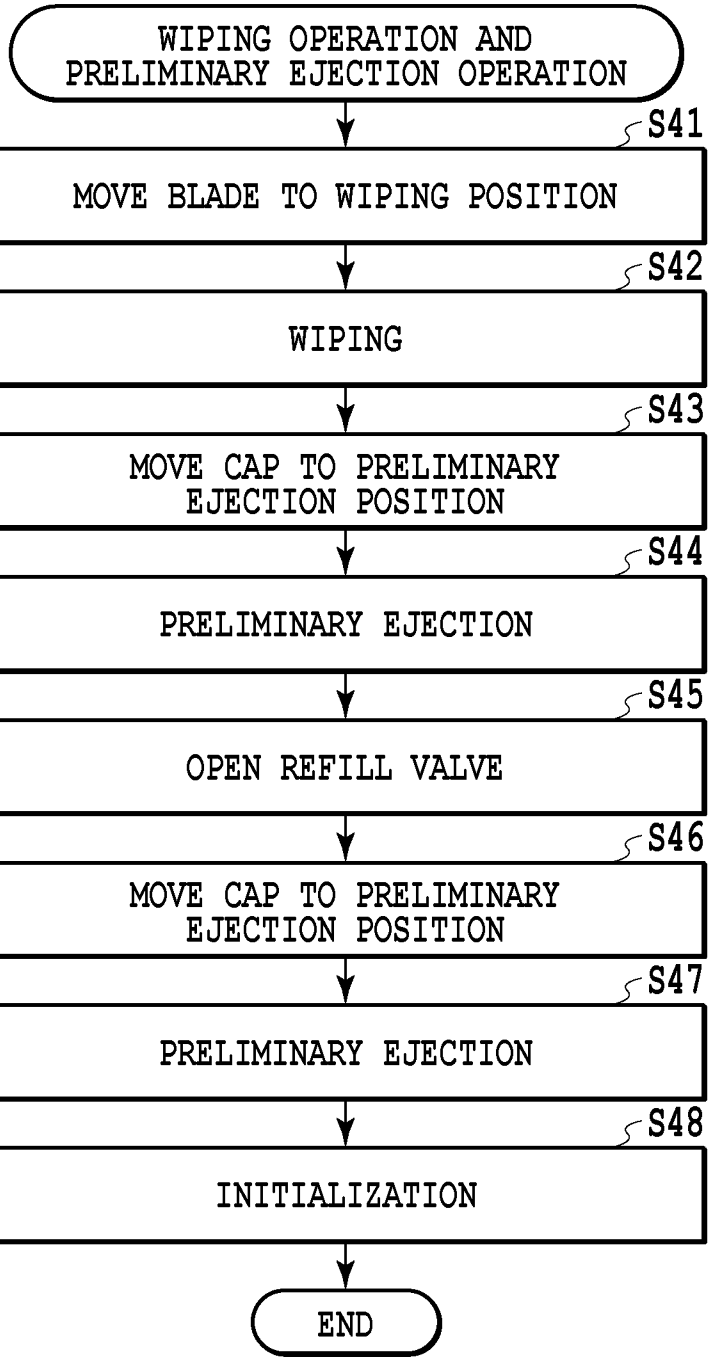

SUCTION-BASED RECOVERY OPERATION (THIRD STAGE)
S31
OPEN BUFFER VALVE
S32
CLOSE REFILL VALVE
S33
OPEN PRESSURE INTRODUCTION VALVE
S34
WAIT UNTIL PREDETERMINED TIME (T4) ELAPSES
S35
CLOSE BUFFER VALVE, AND THEN CLOSE PRESSURE INTRODUCTION VALVE
S36
OPEN RECOVERY VALVE
S37
DRIVE SUCTION PUMP
S38
WAIT UNTIL PREDETERMINED TIME (T5) ELAPSES
S39
OPEN ATMOSPHERE COMMUNICATION VALVE
S40
WAIT UNTIL PREDETERMINED TIME (T6) ELAPSES
S41
HALT SUCTION PUMP
S42
CLOSE RECOVERY VALVE
END

FIG.7



WIPING OPERATION AND PRELIMINARY EJECTION OPERATION
S41
MOVE BLADE TO WIPING POSITION
S42
WIPING
S43
MOVE CAP TO PRELIMINARY EJECTION POSITION
S44
PRELIMINARY EJECTION
S45
OPEN REFILL VALVE
S46
MOVE CAP TO PRELIMINARY EJECTION POSITION
S47
PRELIMINARY EJECTION
S48
INITIALIZATION
END

FIG.8

FIG.9A

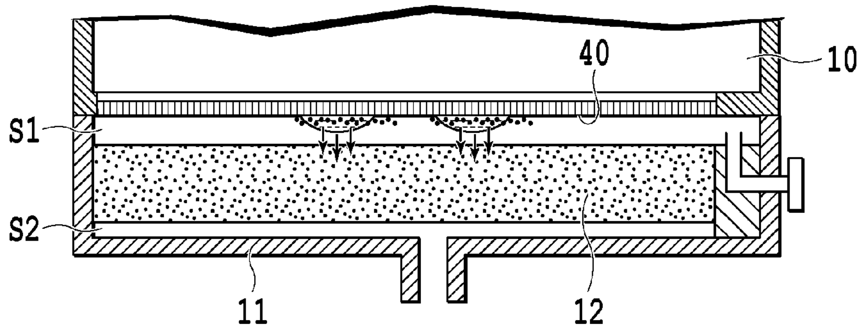


FIG.9B

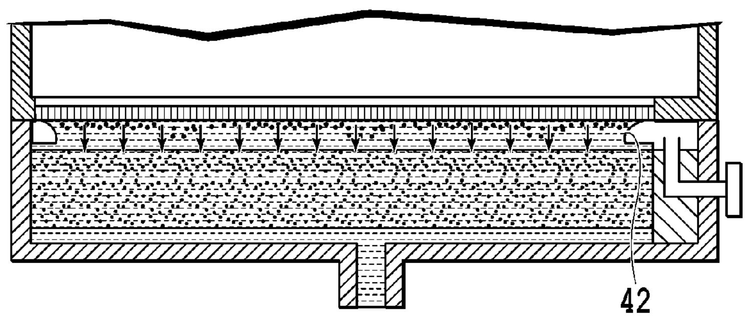


FIG.9C

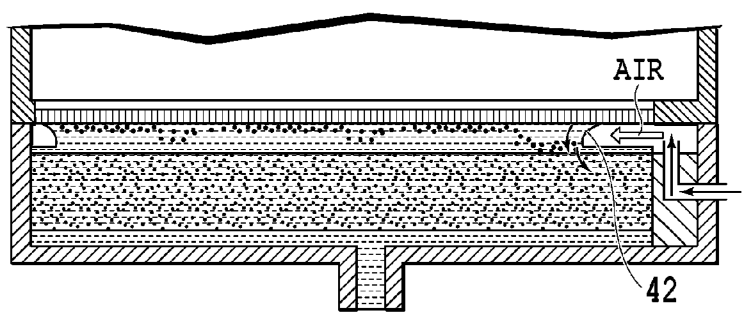


FIG.9D

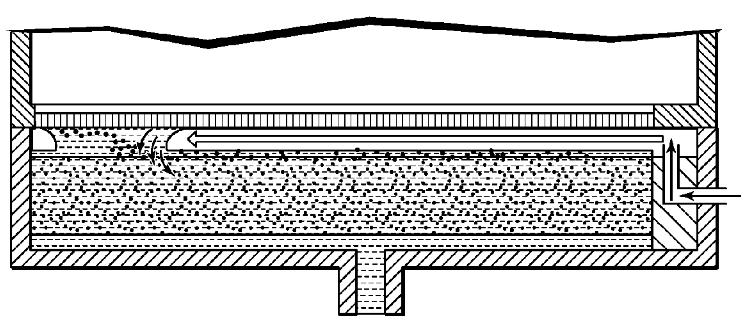


FIG.10A

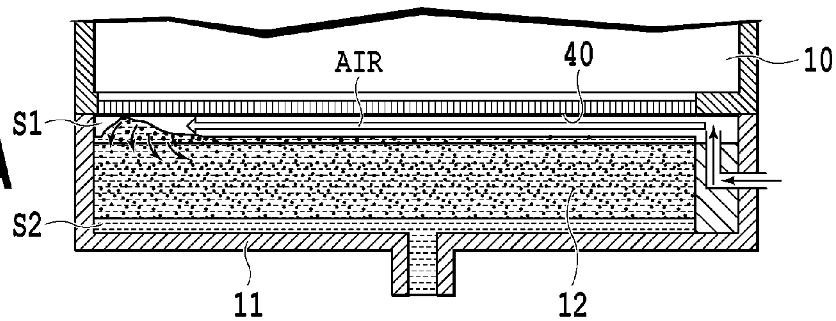


FIG.10B

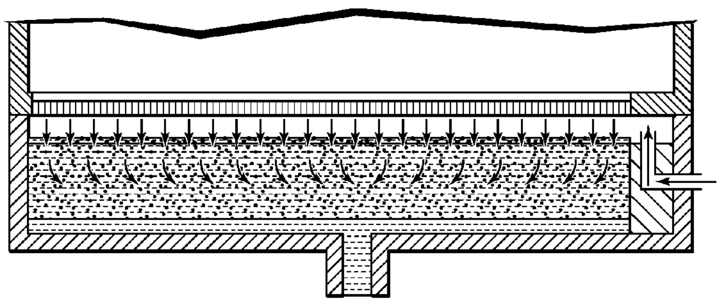


FIG.10C

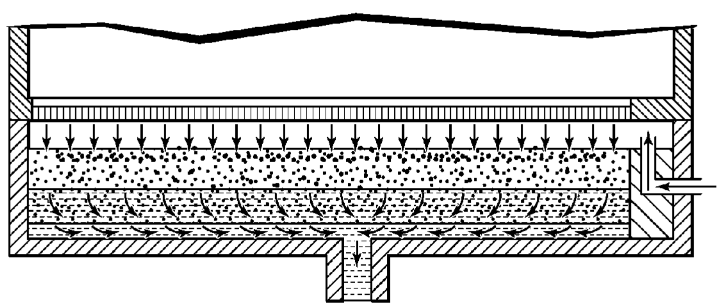
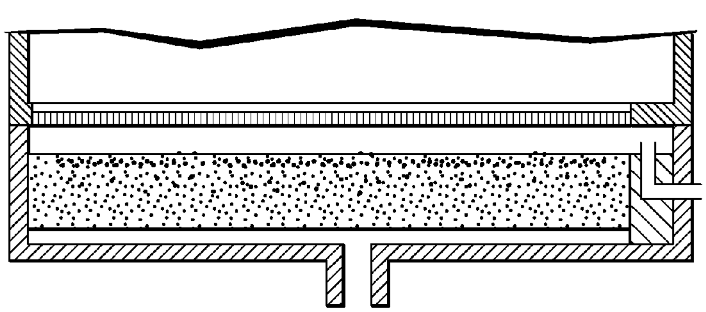


FIG.10D



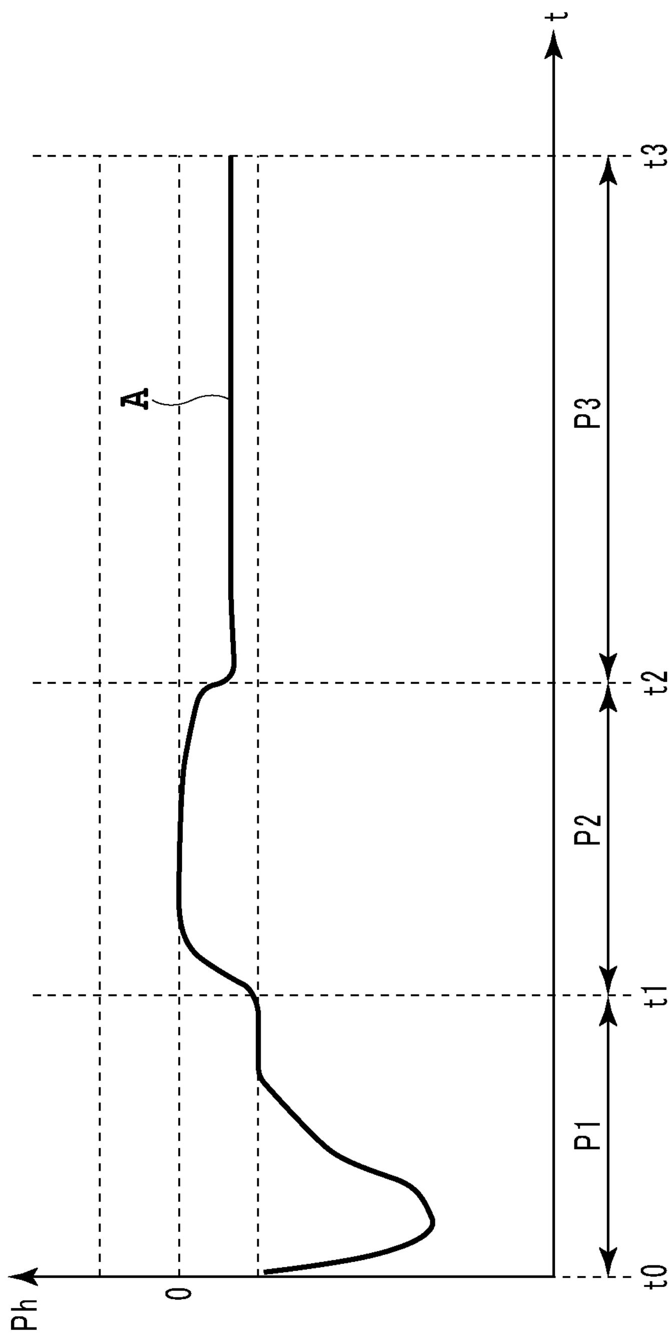


FIG.11

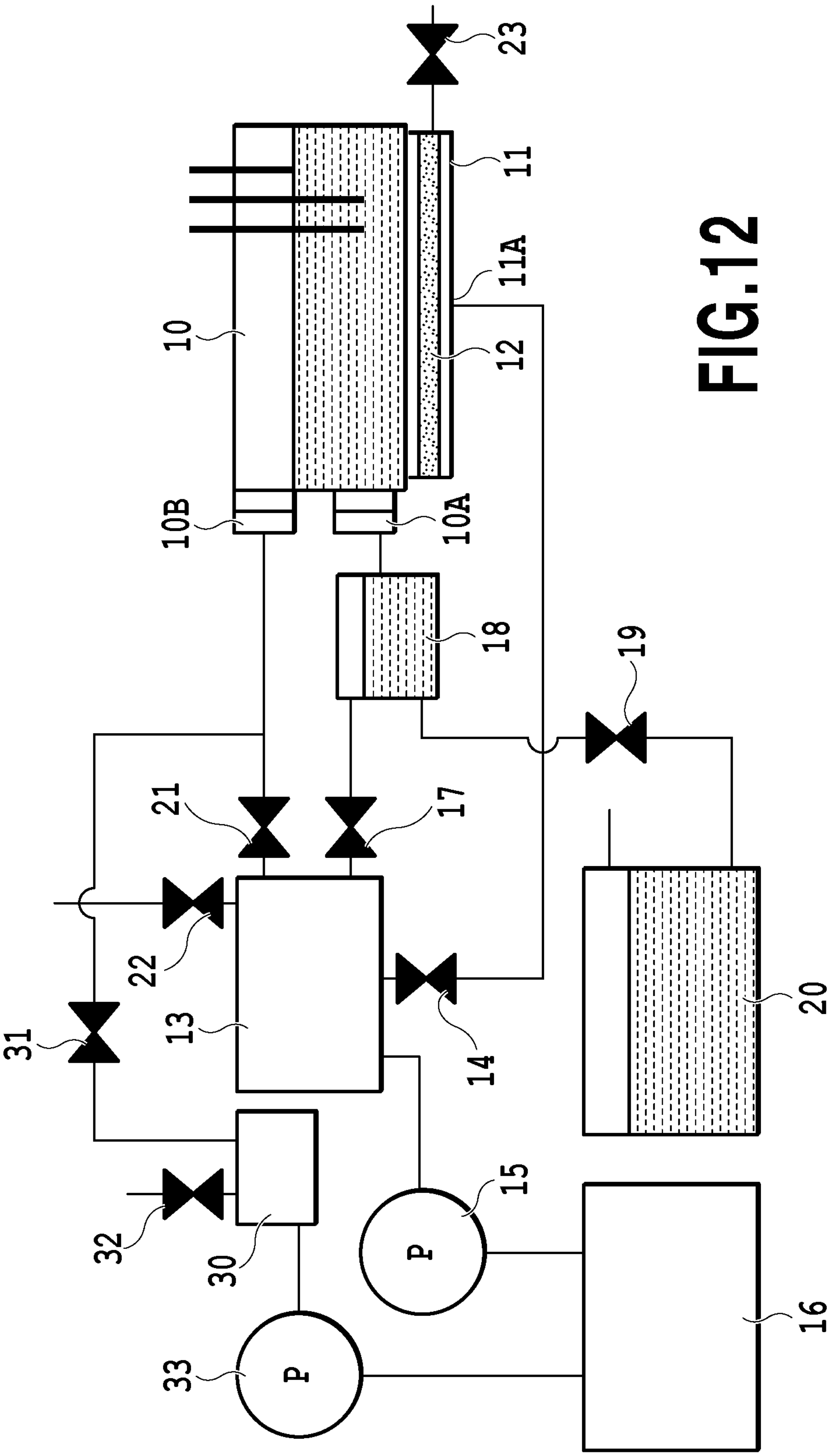


FIG.12

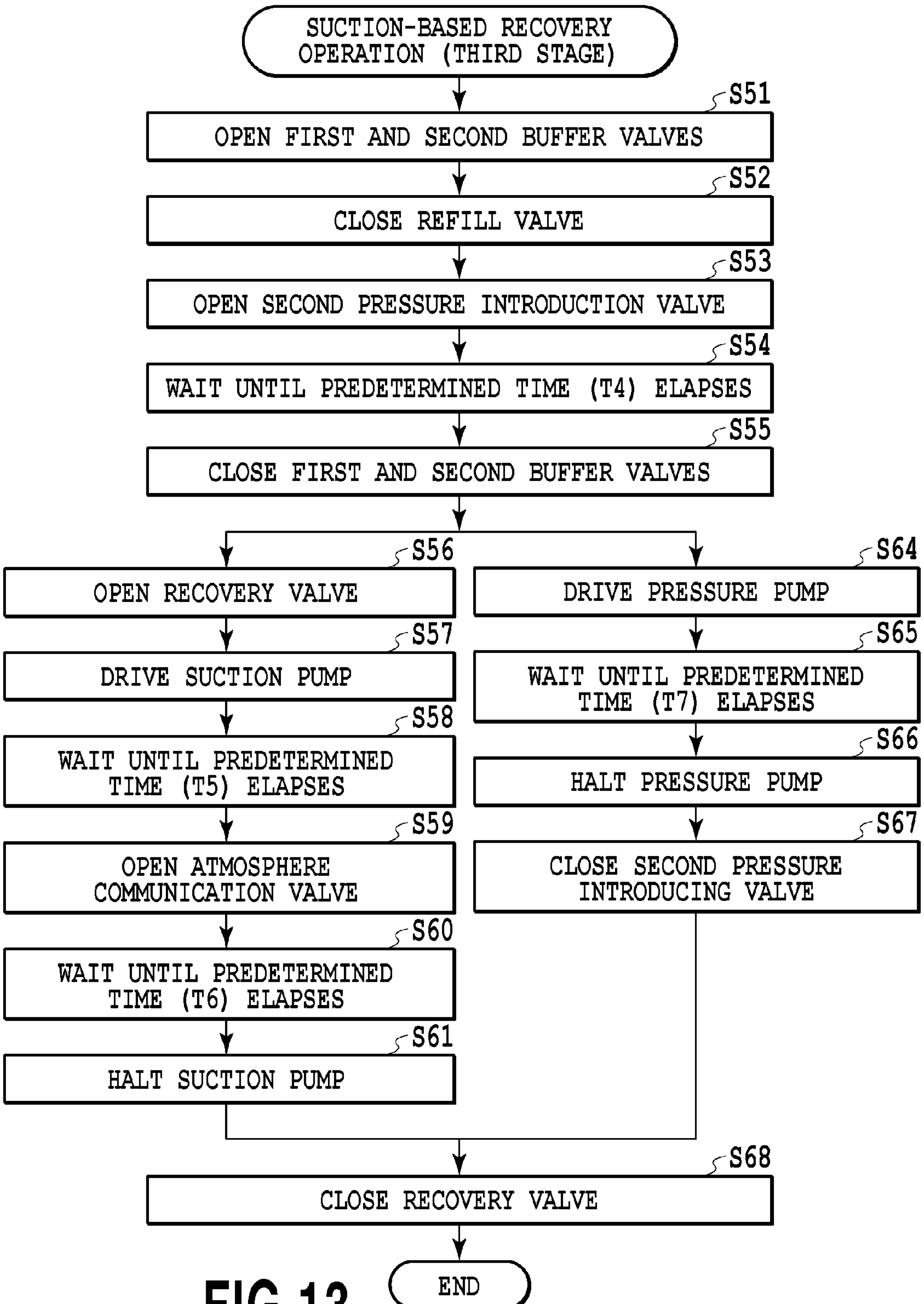

SUCTION-BASED RECOVERY OPERATION (THIRD STAGE)
S51
OPEN FIRST AND SECOND BUFFER VALVES
S52
CLOSE REFILL VALVE
S53
OPEN SECOND PRESSURE INTRODUCTION VALVE
S54
WAIT UNTIL PREDETERMINED TIME (T4) ELAPSES
S55
CLOSE FIRST AND SECOND BUFFER VALVES
S56
OPEN RECOVERY VALVE
S57
DRIVE SUCTION PUMP
S58
WAIT UNTIL PREDETERMINED TIME (T5) ELAPSES
S59
OPEN ATMOSPHERE COMMUNICATION VALVE
S60
WAIT UNTIL PREDETERMINED TIME (T6) ELAPSES
S61
HALT SUCTION PUMP
S64
DRIVE PRESSURE PUMP
S65
WAIT UNTIL PREDETERMINED TIME (T7) ELAPSES
S66
HALT PRESSURE PUMP
S67
CLOSE SECOND PRESSURE INTRODUCING VALVE
S68
CLOSE RECOVERY VALVE
END

FIG.13

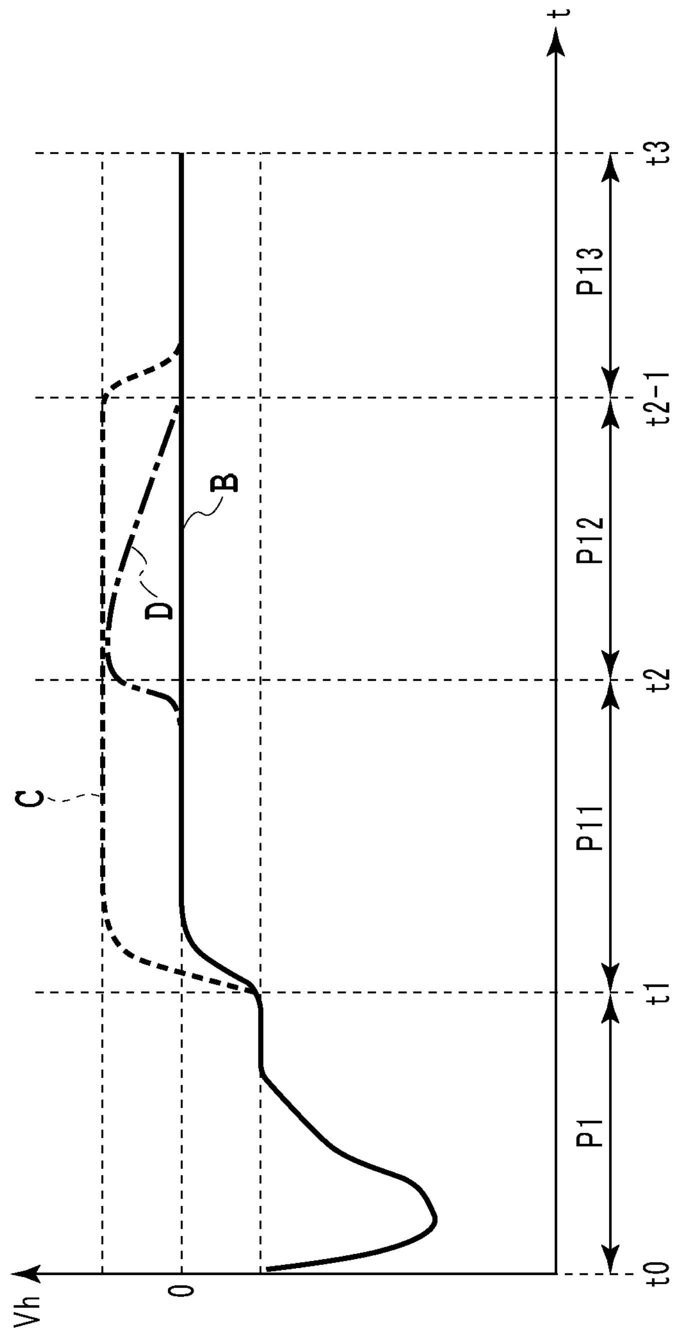


FIG.14

INK JET PRINTING APPARATUS, PRINT HEAD RECOVERY DEVICE AND PRINT HEAD RECOVERY METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an ink jet printing apparatus that performs a suction-based recovery operation for an ink ejection print head, and a print head recovery device and a print head recovery method that are employed to perform the suction-based recovery operation.

2. Description of the Related Art

For an ink jet printing apparatus that prints an image by employing a print head wherein ink can be ejected from ejection ports formed at nozzle tips, a suction-based recovery operation is well known as a recovery operation for maintaining an appropriate ink ejection state for the print head. The suction-based recovery operation is an operation wherein, while the ejection ports of the print head are covered with a cap (a capping state), a negative pressure is generated by a pump and is introduced into the cap to move, by suction, ink that does not contribute to the printing of an image from the ejection ports into the cap. When the suction-based operation is performed, bubbles generated in the nozzles, and viscous ink and foreign substances, such as dust, in the nozzles can be discharged to maintain an appropriate ink ejection state.

According to a printing apparatus described in Japanese Patent Laid-Open No. 2007-118508, after a suction-based recovery operation has been performed, and while the capping state of a print head is being maintained, a suction pump is halted to relax the pressure in the print head and in the cap, and thereafter, an atmosphere communication valve, for connecting the interior of the cap with the atmosphere, is opened. Sequentially, then, in the state wherein the atmosphere communication valve has been opened, the suction pump is restarted to introduce external air into the cap via the atmosphere communication valve, and this air stream is employed to clean an ejection port face of the print head, where the ejection ports are formed at the nozzle tips.

However, in the printing apparatus described in Japanese Patent Laid-Open No. 2007-118508, during a period following the suction-based recovery operation and lasting until the atmosphere communication valve has been opened, the suction pump is merely halted to relax the pressure in the print head and the pressure in the cap. Therefore, when the pressure in the two components is relaxed, the pressure in the cap will be slightly lower than the atmosphere, and in this state, the pressure in the print head and the pressure in the cap are evenly balanced, so that ink will not be discharged from the ejection ports into the cap. However, when in this state the atmosphere communication valve is opened, the pressure in the cap rises, and balance is lost between the pressure in the print head and the pressure in the cap. Thus, there is a possibility that air, introduced through the atmosphere communication valve, and foreign substances in the cap, such as dust and viscous ink, will enter the print head through the ejection ports.

SUMMARY OF THE INVENTION

The present invention provides an ink jet printing apparatus that performs a suction-based recovery operation, while preventing foreign substances from entering a print head, and a print head recovery device and a print head recovery method that are employed to perform the suction-based recovery operation.

In the first aspect of the present invention, there is provided an ink jet printing apparatus for printing an image by employing a print head capable of ejecting ink from ejection ports, comprising:

a cap configured to cover the ejection ports;

a suction unit configured to draw ink from the ejection ports into an interior of the cap by applying a suction force to the interior of the cap that is covering the ejection ports;

an atmosphere communication unit configured to expose to the atmosphere the interior of the cap that is covering the ejection ports;

a pressure increase unit configured to increase a pressure in an internal of the print head; and

a control unit configured to permit the suction unit to apply the suction force to the interior of the cap, and to permit the pressure increase unit to increase the pressure in the internal of the print head before the atmosphere communication unit exposes the interior of the cap to the atmosphere in a state where the ejection ports is covered with the cap.

In the second aspect of the present invention, there is provided a print head recovery processing device for performing a recovery process for a print head capable of ejecting ink from ejection ports, comprising:

a cap configured to cover the ejection ports;

a suction unit configured to draw ink from the ejection ports into an interior of the cap by applying a suction force to the interior of the cap that is covering the ejection ports;

an atmosphere communication unit configured to expose to the atmosphere the interior of the cap that is covering the ejection ports;

a pressure increase unit configured to increase a pressure in an internal of the print head; and

a control unit configured to permit the suction unit to apply the suction force to the interior of the cap, and to permit the pressure increase unit to increase the pressure in the internal of the print head before the atmosphere communication unit exposes the interior of the cap to the atmosphere in a state where the ejection ports is covered with the cap.

In the third aspect of the present invention, there is provided a print head recovery processing method for performing a recovery process for a print head capable of ejecting ink from ejection ports, comprising:

a covering step of covering the ejection ports with a cap;

a drawing step of drawing ink from the ejection ports into an interior of the cap by applying a suction force to the interior of the cap that is covering the ejection ports;

an exposing step of exposing to the atmosphere the interior of the cap that is covering the ejection ports; and

an increasing step of increasing a pressure in an internal of the print head,

wherein, in a state where the ejection ports are covered with the cap, applying the suction force to the interior of the cap at the drawing step and increasing the pressure in the internal of the print head at the increasing step are performed before exposing the interior of the cap to the atmosphere at the exposing step is performed.

According to the present invention, since the internal pressure in the print head is increased after the suction-based recovery process has been performed, and before the interiors of the caps have been connected to the atmosphere, entering of a foreign substance, via the ejection ports, into the interior of the print head can be prevented.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating the arrangement of a printing apparatus according to a first embodiment of the present invention;

FIG. **2** is a block diagram illustrating the arrangement of a portion of the control system of the printing apparatus in FIG. **1**;

FIG. **3** is a schematic diagram illustrating the arrangement of a recovery system employed for the printing apparatus in FIG. **1**;

FIG. **4**A is a cross-sectional view of a cap shown in FIG. **3**;

FIG. **4**B is a cross-sectional view for explaining an example of an absorber in FIG. **4**A;

FIG. **4**C is a cross-sectional view for explaining another example of the absorber in FIG. **4**A;

FIG. **5** is a flowchart for explaining the suction-based recovery operation performed by the recovery system in FIG. **3**;

FIG. **6** is a flowchart for explaining the suction-based recovery operation performed by the recovery system in FIG. **3**;

FIG. **7** is a flowchart for explaining the suction-based recovery operation performed by the recovery system in FIG. **3**;

FIG. **8** is a flowchart for explaining the wiping and preliminary ejection operation performed by the recovery system in FIG. **3**;

FIGS. **9**A, **9**B, **9**C and **9**D are cross-sectional views of a cap during the suction-based recovery operation of the recovery system in FIG. **3**;

FIGS. **10**A, **10**B, **10**C and **10**D are cross-sectional views of a cap during the suction-based recovery operation of the recovery system in FIG. **3**;

FIG. **11** is a diagram for explaining a pressure change for the print head during the suction-based recovery operation of the recovery system in FIG. **3**;

FIG. **12** is a schematic diagram illustrating the arrangement of a recovery system according to a second embodiment of the preset invention;

FIG. **13** is a flowchart for explaining the suction-based recovery operation performed by the recovery system in FIG. **12**; and

FIG. **14** is a diagram for explaining a pressure change for the print head during the suction-based recovery operation of the recovery system in FIG. **12**.

DESCRIPTION OF THE EMBODIMENTS

The embodiments of the present invention will now be described based on the accompanying drawings.

First Embodiment

FIG. **1** is a schematic front view of an ink jet printing apparatus according to a first embodiment of the present invention. An ink jet printing apparatus (hereinafter referred to simply as a printing apparatus) **100** of this embodiment is full-line type printing apparatus, and is connected to a host PC (a host apparatus) **200**. Based on print data received from the host PC **200**, the printing apparatus **100** employs four print heads **10** (**10**K, **10**C, **10**M and **10**Y) to eject black, cyan, magenta and yellow inks, and to print an image on rolled paper (the printing medium) P.

The print heads **10** are elongated line heads that extend across the entire printing region of the rolled paper P in a direction that crosses (in this embodiment, a direction perpendicular to) a direction Y, in which the rolled paper P is to be conveyed. The print head **10**K, for the ejection of black ink, the print head **10**C, for the ejection of cyan ink, the print head **10**M, for the ejection of magenta ink, and the print head **10**Y, for the ejection of yellow ink are arranged in the named order in the conveying direction Y. For each of the print heads **10**, a plurality of nozzles for ejecting ink are arranged in a direction that crosses (in this embodiment, is perpendicular to) the conveying direction Y, and ejection energy elements, such as electrothermal transducing elements (heaters) or piezoelectric elements, are employed to eject ink through these nozzles. When electrothermal transducing elements are employed, heat is generated to form bubbles in the ink, and bubble generation energy is employed to eject the ink through ejection ports at the nozzle tips. The ejection ports are formed in the ejection port faces of the individual print heads **10**.

A recovery unit **110** is provided for the printing apparatus **100**, and includes a recovery processor **105** (see FIG. **2**) for maintaining an appropriate ink ejection state for the print heads **10**. Since the recovery unit **110** periodically cleans the ejection port faces of the print heads **10**, an appropriate ink ejection state for the print heads **10** can be maintained. The recovery unit **110** also includes caps **11** that closely contact (capping) the ejection port faces of the print heads **10** during the cleaning operation.

The rolled paper P is fed by a feeding unit **120**, and is conveyed, in a direction indicated by an arrow Y, by a conveying mechanism **130** included in the printing apparatus **100**. The conveying mechanism **130** of this embodiment employs a conveying belt to convey the rolled paper P.

For the printing of an image, when a printing position on the rolled paper P that is being conveyed has reached a position opposite the print head **10**K, the print head **10**K ejects black ink based on print data received from the host PC **200**. Similarly, the print head **10**C, the print head **10**M and the print head **10**Y eject cyan, magenta and yellow inks, in the named order, and color images are printed on the rolled paper P. The printing apparatus **100** includes cartridge type ink tanks (hereinafter also referred to as “ink cartridges”) **20** (**20**K, **20**C, **20**M and **20**Y), wherein inks are stored that are to be supplied to the individual print heads **10**. An ink supply unit **106** (see FIG. **2**) supplies inks from the ink cartridges **20** to the corresponding print heads **10**.

FIG. **2** is a schematic block diagram illustrating the arrangement of the control system of the printing apparatus **100** in FIG. **1**. A CPU **150** controls the operation of the printing apparatus **100**, and performs the required data processing, in order to perform the processes shown in the flowcharts in FIGS. **5**, **6** and **7**, which will be described later. A ROM **101** is employed for storing programs for these processes, and a RAM **102** is employed as a work area for performing these processes. For the ejection of ink from the print heads **10**, the CPU **150** permits a driver **10**A to drive ejection energy generation elements, such as electrothermal elements. The CPU **150** also employs drivers **105**A, **106**A and **130**A for controlling the recovery processor **105**, the ink supply unit **106** and the conveying mechanism **130**.

FIG. **3** is a schematic diagram illustrating the arrangement of a recovery system that includes the recovery processor **105** and the ink supply unit **106**. Since the same structure is employed for the recovery systems of all the individual print heads **10**, the recovery system for only one print head **10** will be employed for the following description.

The cap **11** is located opposite an ejection port face **40** (see FIG. **4**A) of the print head **10**, and as shown in FIG. **4**A, an absorber **12** provided for the cap **11** divides the inner space of the cap **11** into an ejection port side space S1 and a bottom side space S2. The absorber **12** may have a protruded shape in cross section, as shown in FIG. **4**B, or a shape having a flat upper face, as shown in FIG. **4**C. It should be noted that the cross sections in FIGS. **4**B and **4**C are taken from the side (right side in FIG. **4**A) of the cap **11** in FIG. **4**A. The absorber **12** having the shape, in cross section, shown in FIG. **4**B provides high ink absorption efficiency for ink (including a liquid column that will be described later) during the suction-based recovery operation that will be described later. The possible reason for this is that the portion of the absorber **12** opposite the ejection port face **40** is small, and thus, suction force is concentrated on this portion.

A suction port **11**A, formed in the bottom of the cap **11**, is connected, via a recovery valve **14**, to a buffer **13** used to temporarily store suction pressure that is to be applied to evacuate the interior of the cap **11**. The buffer **13** is connected, via a suction pump **15** that generates a negative pressure, to a maintenance tank **16** used to store waste ink. The print head **10** includes an ink storage portion that communicates with an ink supply port **10**A, and an air extraction chamber **18**, wherein bubbles evacuated from the print head **10** are temporarily stored, is connected to the ink supply port **10**A. The lower portion of the air extraction chamber **18** is connected to the ink cartridge **20** via a refill valve **19**, while the upper portion of the air extraction chamber **18** is connected to the buffer **13** via an air relief valve **17**.

A pressure introduction port **10**B communicates with the upper portion of the ink storage portion of the print head **10**, and is connected to the buffer **13** via a pressure introduction valve **21**. A communication path **41** is formed for the cap **11** to connect the ejection port side space S1 to the atmosphere, as shown in FIG. **4**A, and an atmosphere communication valve **23** is provided for the communication path **41**. Further, as shown in FIG. **4**A, a blade **43** is provided for the cap **11** to wipe the ejection port face **40** of the print head **10**. A buffer valve **22** is provided for the buffer **13** to connect the interior of the buffer **13** with the atmosphere.

During the printing operation, the air relief valve **17** and the pressure introduction valve **21** are closed, and the refill valve **19** is open. Thus, the upper space of the ink storage portion of the print head **10** is a closed space, and a negative pressure due to a difference in hydraulic heads between the print head **10** and the ink cartridge **20** is applied to the ink in the ink storage portion. In accordance with the consumption of ink stored in the print head **10** during the printing operation, the negative pressure in the upper space of the ink storage portion is increased, and when the negative pressure in the upper space has reached a predetermined level or higher, ink from the ink cartridge **20** is supplied to the print head **10**, against a negative pressure that is applied, due to a difference in the hydraulic heads, to the ink in the ink storage portion. In this manner, the negative pressure in the upper space of the ink storage portion is employed to automatically supply ink to the print head **10**. In order to remove bubbles generated in the print head **10**, or air retained in the air extraction chamber **18**, the negative pressure in the buffer **13** is employed to evacuate the bubbles from the print head **10** and discharge them to the maintenance tank **16**, via the air relief valve **17**, the buffer **13** and the suction pump **15**.

Further, in a case where a new print head **10** is mounted wherein ink is not yet present in the ink storage portion thereof, the negative pressure in the buffer **13** that is generated by the suction pump **15** is introduced into the upper space of the ink storage portion through the pressure introduction valve **21**. Since the negative pressure is supplied to the upper space in this manner, ink is supplied from the ink cartridge **20** to the print head **10**, against the negative pressure that is applied to the ink in the ink storage portion due to a difference in hydraulic heads.

Next, the recovery process for the print heads **10** will be described. The recovery process includes the suction-based recovery operation (A), the wiping operation (B) and the preliminary ejection operation (C). These operations will now be described.

(A) Suction-Based Recovery Operation

The suction-based recovery operation can be divided into three sequential stages, a first stage (A-1), a second stage (A-2) and a third stage (A-3). These stages (A-1), (A-2) and (A-3) will now be described.

(A-1) First Stage

FIG. **5** is a flowchart for explaining the first stage of the suction-based recovery operation. The operation shown in the flowchart of FIG. **5** is performed by the CPU **150**.

At the time the first stage of the suction-based recovery operation is initiated, the air relief valve **17**, the pressure introduction valve **21** and the buffer valve **22** are closed, and the refill valve **19** is open. First, while the recovery valve **14** and the atmosphere communication valve **23** are maintained open, the CPU **150** moves the print head **10** and the cap **11** relative to each other so as to closely contact the ejection port face **40** of the print head **10** and the cap **11** (the capping), as shown in FIG. **3** (step S**1**). Then the CPU **150** closes the recovery valve **14** and the atmosphere communication valve **23** (steps S**2** and S**3**) to form a closed space in the cap **11**, and starts the suction pump **15** to retain a predetermined negative pressure V**1** (−40 kPa, in this embodiment) in the buffer **13** (step S**4**).

Thereafter, the CPU **150** opens the recovery valve **14** (step S**5**) and introduces the negative pressure V**1** from the buffer **13** into the cap **11** to withdraw ink, by using suction, from the nozzles of the print head **10**, as shown in FIG. **9**A. As the withdrawal of ink is continued, the ink is absorbed by the absorber **12**, and gradually fills the spaces S1 and S2 in the cap **11**. Then, when a predetermined time period T**1** (five seconds in this embodiment) has elapsed, the CPU **150** closes the recovery valve **14** (steps S**6** and S**7**). Thereafter, the CPU **150** waits for another predetermined time period T**2** (six seconds in this embodiment) whereby a pressure Vh for the print head **10** and a pressure Vc for the cap **11** are relaxed to reduce a difference between these two pressures. It should be noted here that the pressure Vh is the pressure in the upper space of the ink storage portion of the print head **10**. When the pressure Vh and the pressure Vc are relaxed in this manner, a columnar shape as shown in FIG. **9**B is provided for ink between the ejection port face **40** of the print head **10** and the absorber **12**. The ink portion in the columnar shape is also referred to as a liquid column **42**.

When the liquid column **42** has been formed in this manner, the CPU **150** then opens the buffer valve **22** and exposes the interior of the buffer **13** to the atmosphere in order to return the slightly negative pressure in the buffer **13** to that of the atmosphere (step S**9**). Thereafter, when a predetermined time period T**3** (one second in this embodiment) has elapsed, the CPU **150** recloses the buffer valve **22** (steps S**10** and S**11**).

(A-2) Second Stage

FIG. **6** is a flowchart for explaining the second stage of the suction-based recovery operation. The operation shown in the flowchart in FIG. **6** is performed by the CPU **150**.

At the second stage, the CPU **150** performs steps S**21** and S**28**, which correspond to steps S**4** to S**11** of the first stage, to repeat the operation for evacuating ink from the nozzles of the print head **10** by suction. This second suction operation is performed in order to more appropriately form the ink liquid column **42**.

First, the CPU **150** accumulates a predetermined negative pressure V**2** (−10 kPa in this embodiment) in the buffer **13**, and opens the recovery valve **14** (steps S**21** and S**22**). Since the negative pressure V**2** is lower than the negative pressure V1 employed for the previously performed first suction operation, a smaller amount of ink is evacuated by suction than was evacuated at the first stage. Since the amount of ink evacuated this manner is added to a plurality of ink droplets on the ejection port face **40**, a broader liquid column **42** can be formed. Thereafter, when a predetermined time period T**11** (7.5 seconds in this embodiment) has elapsed, the CPU **150** closes the recovery valve **14** (steps S**23** and S**24**). The predetermined period T**11** is longer than the predetermined period T1 at step S**6**, and the evacuation of ink is performed for a longer time than at step S**6**. The CPU **150** waits for another predetermined period T**12** (six seconds in this embodiment) whereby the pressure Vh in the print head **10** and the pressure Vc in the cap **11** are relaxed (step S**25**). As a result, a liquid column **42** that was not completely formed at the first stage can be appropriately obtained. In the state where the liquid column **42** has been formed, the pressure Vc in the cap **11** is slightly lower than the atmosphere, i.e., a negative pressure, and in this state, the pressure Vh in the print head **10** and the pressure Vc in the cap **11** are balanced, so as not to discharge ink from the nozzles into the cap **11**. In a state where the pressure Vh and the pressure Vc are balanced and the ink in the nozzles is not moved, the pressure Vh is not always equal to the pressure Vc because of resistance to flow through the nozzles and the meniscus of ink formed at the ejection ports. The pressure Vh may be lower than the pressure Vc, and is a negative pressure that is lower than the atmospheric pressure.

Following this, the CPU **150** opens the buffer valve **22**, releasing the pressure in the buffer **13** to the atmosphere, in order to return the negative pressure in the buffer **13** to that of the atmosphere (step S**26**). Thereafter, when a predetermined time period T**13** (one second in this embodiment) has elapsed, the CPU **150** recloses the buffer valve **22** (steps S**27** and S**28**).

The graph in FIG. **11** shows a curve A for changing the pressure Ph of the print head **10** during the recovery process, and a period P**1** from time t0 to t1 corresponds to the processing period from step S**21** to S**28**. In FIG. **11**, the atmospheric pressure is set as "0". As described above, until time t1, the pressure Vh and the pressure Vc in the cap **11** are balanced so as not to discharge ink from the nozzles into the cap **11**, and the pressure Vh at this time is a negative pressure that is slightly lower than the atmospheric pressure.

(A-3) Third Stage

FIG. **7** is a flowchart for explaining the third stage of the suction-based recovery operation. The operation shown in the flowchart in FIG. **7** is performed by the CPU **150**.

First, the CPU **150** opens the buffer valve **22** to release the pressure in the buffer **13** to the atmosphere (step S**31**). Then, the CPU **150** closes the refill valve **19** and opens the pressure introduction valve **21** (steps S**32** and S**33**) to introduce the atmospheric pressure of the buffer **13** into the print head **10**. When the atmospheric pressure of the buffer **13** is introduced into the print head **10**, which is under a slightly negative pressure, the pressure Vh of the print head **10** is increased, and the balance between the pressure Vh and the pressure Vc, to avoid the discharge of ink from the nozzles into the cap **11**, is lost. Thus, a small amount of ink is discharged from the nozzles into the cap **11**. At this time, since the liquid column **42** has been formed, and the meniscus of the ink does not affect the nozzles, the discharge of ink from the nozzles into the cap **11** occurs easily. When a small amount of ink has been discharged, the pressure Vh and the pressure Vc again become balanced and do not discharge ink through the nozzles.

The refill valve **19** is closed at step S**32** because when the atmospheric pressure in the buffer **13** is introduced into the print head **10**, which is under a slightly negative pressure, the falling of ink from the print head **10** to the ink cartridge **20** is prevented. There is a hydraulic head difference between the print head **10** and the ink cartridge **20**, and in a case where the atmospheric pressure is introduced into the print head **10** while the refill valve **19** is maintained open, ink in the print head **10** may drop into the ink cartridge **20**. Further, when the refill valve **19** is closed, the movement range of the ink in the print head **10** can be limited to the nozzles and the cap **11**, and therefore, the pressure Vh of the print head **10** is easily controlled.

Sequentially, when a predetermined time period T**4** (one second in this embodiment) has elapsed (step S**34**), the CPU **150** closes the buffer valve **22**, and thereafter closes the pressure introduction valve **21** (step S**35**) and opens the recovery valve **14** (step S**36**). The recovery valve **14** is opened before the atmosphere communication valve **23** is opened to prevent the leakage of ink from the cap **11** to the exterior via the atmosphere communication valve **23**. That is, although the pressure Vh and the pressure Vc are again balanced to prevent the discharge of ink from the nozzles, there is a possibility that, since a small amount of ink was previously discharged through the nozzles, the pressure Vc will be higher than the atmospheric pressure. In a case where the recovery valve **14** is kept closed and the atmosphere communication valve **23** is open, ink in the cap **11** may leak externally, via the atmosphere communication valve **23**. In order to prevent such an ink leakage, the recovery valve **14** is opened prior to the atmosphere communication valve **23**, and the atmospheric pressure is introduced into the cap **11** to return the pressure Vc to the atmospheric pressure level.

Thereafter, the CPU **150** drives the suction pump **15** (step S**37**) to withdraw ink, in a predetermined volume (0.1 cc/sec in this embodiment), from the cap **11** via the buffer **13** and the recovery valve **14**. Since the suction pump **15** is driven after the recovery valve **14** has been opened, a change in the pressure in the cap **11** can be moderate, and an undesirable effect provided by a sharp change in the pressure can be avoided. When a predetermined time period T**5** (one second in this embodiment) has elapsed (step S**38**), the CPU **150** permits a flow of ink from the cap **11** to the buffer **13**, and opens the atmosphere communication valve **23** (step S**39**) to introduce air into the cap **11**.

Sequentially, then, when a predetermined time period T**6** (**25** seconds in this embodiment) has elapsed (step S**40**), the CPU **150** halts the suction pump **15** (step S**41**), and closes the recovery valve **14** (step S**42**).

As described above, the pressure Vh in the print head **10** and the pressure Vc in the cap **11** are balanced to prevent the discharge of ink through the nozzles, the drawing of ink into the cap **11** is performed to generate a flow of ink, and the atmosphere communication valve **23** is opened to introduce air into the cap **11**. As a result, as shown in FIGS. **9**C and **9**D and FIGS. **10**A, **10**B, **10**C and **10**D, the ink in the cap **11** flows in directions indicated by arrows, and is discharged in the manner that the liquid column **42** is pulled apart from the ejection port face **40** and is discharged. Since ink flows in the cap **11** in this manner, ink droplets seldom remain on the ejection port face **40**, and dust is removed from the ejection port face **40** by the flow of ink. Since the surface tension of ink is applied to the liquid column **42**, the liquid column **42** is drawn in through the absorber **12** that is held in the cap **11**.

Furthermore, when the atmosphere communication valve **23** is to be opened, the pressure Vh in the print head **10**, which is the atmospheric pressure, is equal to, or slightly higher than the pressure Vc in the cap **11**, and the occurrence of a back-flow of ink from the cap to the nozzles is suppressed.

In FIG. **11**, a period P**2**, from time t1 to time t2 corresponds to a processing period from step S**31** to step S**38**. At time t1, the pressure introduction valve **21** is open, and the atmospheric pressure is introduced into the print head **10**. A period P**3** from time t2 to time t3 corresponds to a processing period from step S**39** to step S**42**. At time t2, the atmosphere communication valve **23** is opened and the atmospheric pressure is introduced into the cap **11**.

(B) Wiping Operation and (C) Preliminary Ejection Operation

FIG. **8** is a flowchart for explaining the wiping operation and the preliminary ejection operation. The operations shown in the flowchart in FIG. **8** are performed by the CPU **150**.

First, the CPU **150** moves the cap **11** relative to the print head **10** to cancel capping by the cap **11**, and as shown in FIG. **4**A, moves the blade **43**, provided for the cap **11**, to the wiping position for the print head **10** (step S**41**). Following this, the CPU **150** moves the cap **11** to the right of the print head **10** in FIG. **4**A, and employs the blade **43** to wipe the ejection port face **40** (step S**42**). The wiping using the blade **43** is performed in an arbitrary direction, and a direction parallel to, or perpendicular to the nozzle array, may be employed.

Then, the CPU **150** moves the cap **11**, relative to the print head **10**, to the preliminary ejection position (step S**43**). The preliminary ejection operation is an operation for ejecting, through the nozzles of the print head **10**, ink that does not contribute to the printing of an image, and the cap **11** is moved to the preliminary ejection position to accept ink ejected during the preliminary ejection. Thereafter, the CPU **150** performs the preliminary ejection (step S**44**).

Following this, the CPU **150** opens the refill valve **19** (step S**45**) to apply, to the print head **10**, a negative pressure that is due to a difference in hydraulic heads between the print head **10** and the ink cartridge **20**. Thereafter, the CPU **150** moves the cap **11** to the preliminary ejection position, and performs the preliminary ejection in order to adjust the meniscus of ink formed at the ejection ports of the nozzle tips (steps S**46** and S**47**), and performs an initialization process required to terminate the recovery process (step S**48**).

Second Embodiment

FIG. **12** is a schematic diagram illustrating the arrangement of a recovery system according to a second embodiment of the present invention. The same reference numerals as used in FIG. **3** for the first embodiment are also provided for corresponding portions, and no further explanation for them will be given.

In this embodiment, a pressure pump **33** that generates a positive pressure, a buffer **30** that temporarily stores the pressure generated by the pressure pump **33**, and a pressure introduction valve **31** are connected between a maintenance tank **16** and a pressure introduction port **10**B of a print head **10**. The pressure pump **33** serves as a pressurization portion that applies the atmospheric pressure, or higher, to the inside of the print head **10**. The buffer **30** includes a buffer valve **32** for releasing the internal pressure to the atmosphere, and the pressure pump **33**, the pressure introduction valve **31** and the buffer valve **32** are electrically connected to a CPU **150**, which controls these components. In the following description, the buffer **13** and the pressure introduction valve **21**, provided for the suction pump **15**, are referred to as a "first buffer **13**" and a "first pressure introduction valve **21**", while the buffer **30** and the pressure introduction valve **31**, provided for the pressure pump **33**, are referred to as a "second buffer **30**" and a "second pressure introduction valve **31**".

As described above, the recovery system of this embodiment includes the two pumps **15** and **33** that respectively generate a negative pressure and a positive pressure, relative to the atmospheric pressure, and the two buffers **13** and **30** that are provided for the corresponding pumps **15** and **33**. The pressures in the buffers **13** and **30** are supplied through the corresponding pressure introduction valves **21** and **31** to the pressure introduction port **10**B of the print head **10**. Since a pressure lower than the atmospheric pressure and a pressure higher than the atmospheric pressure are supplied to the pressure introduction port **10**B, active control of the pressure Vh for the print head **10** can be performed in a way that either increases or reduces the pressure. So long as such control is practiced, another arrangement can be employed, e.g., an arrangement where one buffer is divided into two chambers, or an arrangement where a single pump having the functions of the two pumps **15** and **33** is provided.

Since the suction pump **15** and the buffer **13** are employed for the recovery process of the print head **10**, the suction-based recovery operation (A) described in the first embodiment can also be performed for this embodiment.

Furthermore, in this embodiment, suction-based recovery operation (D), which differs from the suction-based recovery operation (A), can also be performed. The suction-based recovery operation (D) will be described below.

(D) Suction-Based Recovery Operation

This suction-based recovery operation can be divided into three sequential stages, i.e., a first stage (D-1), a second stage (D-2) and a third stage (D-3). The first and second stages (D-1) and (D-2) are the same as the first and second stages (A-1) and (A-2) of the suction-based recovery operation (A) described above for the first embodiment. The third stage (D-3) will now be described based on the flowchart in FIG. **13**. The operation shown in the flowchart in FIG. **13** is performed by the CPU **150**.

The processing from steps S**51** to S**55** in FIG. **13** is the same as the processing from steps S**31** to S**35** in FIG. **7**, which were previously described. It should be noted, however, that, at step S**51**, the CPU **150** opens both the first buffer valve **22** and the second buffer valve **32**, and at step S**55**, the CPU **150** closes the first buffer valve **22** and the second buffer valve **32**. Following step S**55**, the CPU **150** performs, in parallel, the process sequence from steps S**56** to S**61** (hereinafter referred to as a "first process") and the process sequence from step S**64** to S**67** (hereinafter referred to as a "second process").

The first process is a process related to pressure control for the cap **11**, and steps S**56** to S**61** correspond to steps S**36** to S**41** in FIG. **7**, which were described above. That is, the CPU **150** opens a recovery valve **14** and thereafter drives the suction pump **15** (steps S**56** and S**57**), and when a predetermined time period T**5** has elapsed (step S**58**), the CPU **150** permits the ink to flow from the cap **11** to the buffer **13**, and opens an atmosphere communication valve **23** (step S**59**). As a result, air is introduced into the cap **11**. And following this, when the predetermined time period T**6** has elapsed, the CPU **150** halts the suction pump **15** (step S**61**), and closes the recovery valve **14** (step S**68**).

The second process is a process related to the pressure control for the print head **10**. In the second process, the CPU **150** drives the pressure pump **33** (step S**64**), and introduces the pressure, applied by the pressure pump **33**, via the second buffer **30** into the pressure introduction port **10**B of the print head **10**. Since the pressure pump **33** is driven after the second pressure introduction valve **31** is opened, the pressure in the print head **10** can be moderately changed, and an effect provided by a sharp change in the pressure can be avoided. Sequentially, when a predetermined time period T7 has elapsed (S**65**), the CPU **150** halts the pressure pump **33** (step S**66**), and closes the second pressure introduction valve **31** (step S**67**).

When the first process is performed at the third stage (D-3) in FIG. **13**, the control for changing the pressure Ph in the print head, as indicated by the curve A in FIG. **11**, can be performed (hereinafter also referred to as the first control). Further, when the first process and the second process are performed at the same time, and in association with each other, control for changing the pressure Ph in the print head **10**, as indicated by curves B, C and D in FIG. **14**, can be performed (hereinafter also referred to as the second, the third and the fourth control). A period P**1** from time t0 to t1 is the same as the period P**1** shown in FIG. **11**.

The control for changing the pressure Ph, as indicated by the curve B (the second control), the control for changing the pressure Ph, as indicated by the curve C (the third control), and the control for changing the pressure Ph, as indicated by the curve C (the fourth control), will now be described.

(Second Control)

As shown in FIG. **11**, for the first control described above, at time t2, whereat the atmosphere communication valve **23** was opened, the pressure Vh in the print head **10** began to drop to the level of the atmospheric pressure, or lower. For the second control, a small pressure force generated by the pressure pump **33** is introduced into the print head **10**, so that the pressure Vh in the print head **10** is continued to maintain at the atmospheric pressure level, as indicated by the curve B in FIG. **14**, in a period following time t2, whereat the atmosphere communication valve **23** was opened. Specifically, the pressure pump **33** and the pressure introduction valve **31** are controlled to introduce a small pressure force into the print head **10** in synchronization with the time for opening the atmosphere communication valve **23**.

According to the second control, while the balance between the pressure Vh and the pressure Vc is maintained to prevent the discharge of ink through the nozzles, air can be introduced into the cap **11**, via the atmosphere communication valve **23**, by employing the pressure Vh at the atmospheric pressure level. Therefore, as well as in the first embodiment, the occurrence of a backflow of ink to the nozzles can be prevented when the atmosphere communication valve **23** is open.

(Third Control)

In the third control, a small pressure force generated by the pressure pump **33** is introduced into the print head **10** at time t1, whereat the pressure introduction valve **21** was opened and the atmospheric pressure was introduced into the print head **10**. As a result, as indicated by the curve C in FIG. **14**, the pressure Vh in the print head **10** is increased to the atmospheric pressure level or higher. Then, at time t1, since the liquid column **42** described above is formed, and since meniscus force of ink at the nozzles is zero, a small amount of ink is discharged from the nozzles by introducing a small pressure force into the print head **10**, and accordingly, the flow of ink occurs in the print head **10**. Since a small amount of ink is discharged through the nozzles, a backflow of ink to the nozzles can be more appropriately prevented. In this state, the suction force of the suction pump **15** is applied to the cap **11** to draw ink from the nozzles into the cap **11**.

Following time t2, where the atmosphere communication valve **23** is open, the introduction of a small pressure force into the print head **10** is continued to maintain the pressure Vh at the atmospheric pressure level or higher. At time t2-1 whereat the discharge of the liquid column **42** is completed, the introduction of the small pressure force is halted, and the pressure Vh becomes the atmospheric pressure. Therefore, the introduction of the small pressure force is performed during periods P**11** and P**12**, extended from time t1 to time t2-1, and in a period P**13**, following time t2-1, the pressure Vh is reduced to the atmospheric pressure.

According to the third control, while the balance between the pressure Vh and the pressure Vc is maintained to prevent the discharge of ink through the nozzles, air can be introduced into the cap **11** via the atmosphere communication valve **23** by employing the pressure Vh at the atmospheric pressure level or higher. Therefore, as well as in the first embodiment, the occurrence of a backflow of ink to the nozzles can be prevented when the atmosphere communication valve **23** is open.

(Fourth Control)

For the fourth control, as indicated by the curve D in FIG. **14**, a little before time t2, whereat the atmosphere communication valve **23** is open, a small pressure force is introduced into the print head **10** to increase the pressure Vh to the atmospheric pressure level or higher, and in a period P**12**, the pressure Vh of the print head **10** is gradually reduced to the atmospheric pressure.

According to the fourth control, as well as the third control, while the balance of the pressure Vh and the pressure Vc is maintained to prevent the discharge of ink through the nozzles, the air can be introduced into the cap **11** via the atmosphere communication valve **23** by employing the pressure Vh at the atmospheric pressure or higher. Therefore, as well as in the first embodiment, the occurrence of a backflow of ink to the nozzles can be prevented when the atmosphere communication valve **23** is open.

Other Embodiment

When at the least, at time t2 whereat the atmosphere communication valve **23** is open, the pressure Vh in the print head **10** is raised to the atmospheric pressure or higher, in the manner performed for the first to the fourth control, the occurrence of a backflow of ink to the nozzles can be prevented when the atmosphere communication valve **23** is open. Therefore, it is simply required that by time t2, the pressure Vh will have been increased, up to the atmospheric pressure level or higher, and an arbitrary period of time for controlling the pressure Vh can be designated. Further, it is preferable that the upper limit, to which to increase the pressure Vh to the atmospheric pressure level or higher, be within a range wherein the balance of the pressure Vh and the pressure Vc can be maintained to prevent the discharge of ink through the nozzles. However, as described above, the upper limit may be within the range wherein a small amount of ink is discharged through the nozzles.

When the pressure Vh is too high, there is a possibility that, after the suction-based recovery operation has been performed, external air may enter the nozzles when a negative pressure, required for printing, is again applied to the ink in the print head **10** by employing a difference in hydraulic heads between the print head **10** and the ink cartridge **20**. The pressure Vh should be set by also taking this point into account.

Furthermore, the pressure Vh in the print head **10** is not always increased to the atmospheric pressure level or higher, and need only be increased to a level whereat to prevent the occurrence of a backflow of ink in the nozzles when the atmosphere communication valve **23** is open. That is, it is simply required that, before the inside of the cap is exposed to the atmosphere, a suction force is applied to the interior of the cap, and the internal pressure in the print head is increased.

So long as the cap can cover the ejection ports of the print head, the structure of the cap is not especially limited. Furthermore, the structure of the atmosphere communication portion that can expose the interior of the cap to the atmosphere, and the structure of the pressure increasing portion, which can raise the internal pressure of the print head, are not limited to those described in the embodiments, and other, arbitrary structures may be employed. Furthermore, the structure for applying a negative pressure to ink in the print head is not limited to the structure that employs a difference in hydraulic heads, and a negative pressure application portion, such as an ink absorber, may be employed.

The present invention can be widely applied for various types of ink jet printing apparatuses other than the full-line type, such as a serial scan type. The print head recovery processor for this invention can handle various print heads for ejecting ink, and may be provided as a processing system installed in a printing apparatus, or as a processing system prepared separately from any printing apparatus.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2013-017176, filed Jan. 31, 2013, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An ink jet printing apparatus for printing an image, the apparatus comprising:
- a print head having:
  - ejection ports capable of ejecting ink;
  - an ink supply port, ink being supplied to the print head through the ink supply port; and
  - a pressure introduction port, the pressure introduction port being different from the ink supply port;
- a cap configured to cover the ejection ports;
- a suction unit configured to draw ink from the ejection ports into an interior of the cap by applying a suction force to the interior of the cap;
- an atmosphere communication unit configured to expose to the atmosphere the interior of the cap;
- a pressure increase unit configured to increase a pressure in an internal of the print head through the pressure introduction port of the print head;
- a disconnecting unit capable of disconnecting an ink supply path connected to the ink supply port; and
- a control unit configured (i) to control the suction unit to apply the suction force to the interior of the cap, (ii) to control the pressure increase unit to increase the pressure in the internal of the print head in a state where the disconnecting unit disconnects the ink supply path, and (iii) to control the atmosphere communication unit to expose the interior of the cap to the atmosphere in a state where the ejection ports are covered with the cap.

2. The ink jet printing apparatus according to claim **1**, wherein the pressure increase unit includes an exposure portion configured to expose the interior of the print head to the atmosphere through the pressure introduction port.

3. The ink jet printing apparatus according to claim **1**, wherein the pressure increase unit includes a pressure application portion configured to apply a pressure, at the atmospheric level or higher, to the interior of the print head through the pressure introduction port.

4. The ink jet printing apparatus according to claim **1**, wherein the control unit controls the suction unit to apply the suction force to the interior of the cap, and to thereafter control the pressure increase unit to increase the pressure in the interior of the print head.

5. The ink jet printing apparatus according to claim **1**, wherein the control unit controls the suction unit to apply the suction force to the interior of the cap, and concurrently controls the pressure increase unit to increase the pressure in the interior of the print head.

6. The ink jet printing apparatus according to claim **1**, further comprising an absorber configured to divide the interior of the cap into a space opposite the ejection ports and a space to which the suction force is applied by the suction unit.

7. A print head recovery processing device for performing a recovery process for a print head capable of ejecting ink from ejection ports, ink being supplied to the print head through an ink supply port of the print head, the device comprising:
- a cap configured to cover the ejection ports;
- a suction unit configured to draw ink from the ejection ports into an interior of the cap by applying a suction force to the interior of the cap;
- an atmosphere communication unit configured to expose to the atmosphere the interior of the cap;
- a pressure increase unit configured to increase a pressure in an internal of the print head through a pressure introduction port of the print head, the pressure introduction port being different from the ink supply port;
- a disconnecting unit capable of disconnecting an ink supply path connected to the ink supply port; and
- a control unit configured (i) to control the suction unit to apply the suction force to the interior of the cap, (ii) to control the pressure increase unit to increase the pressure in the internal of the print head in a state where the disconnecting unit disconnects the ink supply path, and (iii) to control the atmosphere communication unit to expose the interior of the cap to the atmosphere in a state where the ejection ports are covered with the cap.

8. A print head recovery processing method for performing a recovery process for a print head capable of ejecting ink from ejection ports, ink being supplied to the print head through an ink supply port of the print head, the method comprising:
- a covering step of covering the ejection ports with a cap;
- a drawing step of drawing ink from the ejection ports into an interior of the cap by applying a suction force to the interior of the cap in a state where the ejection ports are covered with the cap;
- a disconnecting step of disconnecting an ink supply path connected to the ink supply port;
- an increasing step of increasing a pressure in an internal of the print head through a pressure introduction port of the print head in a state where the ink supply path is disconnected at the disconnecting step, the pressure introduction port being different from the ink supply port; and
- an exposing step of exposing to the atmosphere the interior of the cap.

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